Usability Study of the CICERONE App for Telemonitoring COPD Patients

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***Abstract*—Telemedicine is a promising tool for the management of Chronic Obstructive Pulmonary Disease (COPD), but its implementation faces challenges related to, among other issues, patient acceptance and usability. In this context, the effectiveness of telemonitoring systems depends not only on their accuracy in predicting exacerbations but also on their ability to integrate intuitively and efficiently into users' daily lives. The CICERONE project has developed a multimodal home telemonitoring system for COPD patients that collects data on symptoms, environmental parameters, lifestyle, and biomedical information. This work presents a study focused on the system's usability, evaluated in three stages: a) initial testing of a mock-up with patients; b) functional trials with volunteers; and c) final testing with patients participating in the project. The development followed an iterative approach based on user feedback and evaluations using the System Usability Scale (SUS). The results highlight how iteration and user-centered design have improved the patient experience and optimized the system's functionality. This study underscores the importance of usability in the design of telemonitoring tools to ensure their adoption and effectiveness in real clinical settings, promoting a more personalized and proactive approach to COPD management.**

Keywords-COPD; Usability; Telemonitoring; Telemedicine; Exacerbation.

I. Introduction

Chronic Obstructive Pulmonary Disease (COPD) is described as a heterogeneous lung disorder manifested by persistent respiratory symptoms, such as dyspnea, cough, sputum production, and acute exacerbations. These manifestations are associated with alterations in the airways, such as bronchitis or bronchiolitis, and in the alveoli, such as emphysema, resulting in progressive and persistent airflow obstruction [1]. COPD is a severe and debilitating disease that poses a significant challenge to healthcare systems due to its high prevalence and impact on morbidity and mortality [2]. According to the World Health Organization (WHO), it is currently the third leading cause of death worldwide [3], responsible for approximately 3.23 million deaths annually, with a projected increase to over 4.5 million by 2030.

The course of this disease is characterized by the occurrence of exacerbations, acute episodes of worsening respiratory symptoms [4]. These exacerbations not only affect lung function but also negatively impact the mental health of patients and worsen comorbidities. As a result, the disease progresses, and patients experience a progressive decline that leads to high healthcare resource consumption. Moreover, exacerbations increase the likelihood of recurrence, and more than 20% of patients hospitalized for this cause die within the year following discharge [5]. This highlights the need to detect and manage these crises early to mitigate their impact on disease progression, patient quality of life, and the economic costs borne by healthcare systems and associated with the management of this condition.

Home telemonitoring has emerged as a promising strategy to prevent exacerbations in COPD patients. Home monitoring of these patients has significantly evolved in recent years with the development of telemedicine systems and wearable devices capable of measuring physiological parameters in real time. Various strategies have been proposed, including the use of sensors to measure oxygen saturation, respiratory rate, physical activity, and sleep quality, as well as mobile applications for symptom tracking and electronic questionnaires [6].

However, the evidence regarding its impact on the reduction of exacerbations and hospitalizations remains uncertain [7], due to the heterogeneity of studies, the lack of reliable predictors [8], low patient adherence [9], and the absence of robust predictive models [10] that integrate health factors, lifestyle, and environmental conditions. Among the current challenges are the identification of clinically relevant predictors, the development of clinically validated algorithms, and the implementation of strategies that minimize the burden on patients, fostering their engagement with treatment. To date, no multimodal tool exists capable of integrating data on respiratory events, lifestyle, acoustic markers of cough and voice, psychomotor tests, respiratory function, patterns of nocturnal physiological variability, and environmental factors to predict the progression of COPD [11]. Usability is a key factor in the home monitoring of COPD patients as it directly influences adherence, system effectiveness, and ultimately clinical outcomes.

COPD patients are often older adults with physical and

cognitive limitations, so a difficult-to-use system may reduce their willingness to use it continuously. An intuitive and accessible interface facilitates its adoption and sustained use. Additionally, if telemonitoring requires too many complex interactions, it may lead to frustration and demotivation. A user-centered design, with simple and automatic interactions, reduces this burden and improves the patient experience. A poorly designed system interface can result in errors in data entry or interpretation by the patient. Good usability ensures that the recorded data is accurate and reliable. Moreover, for telemonitoring to be effective, it must integrate seamlessly into the patient's daily life in a non-invasive way, so that it is perceived as support rather than a burden. Finally, good usability enhances adherence and the quality of the data collected, allowing predictive models and personalized interventions to function more efficiently. Ultimately, usability is not just a design issue, but a fundamental requirement to ensure the adoption and effectiveness of telemonitoring in COPD patients.

In this context, the CICERONE project [12] proposes a patient-centered approach to identify new physiological and environmental indicators, as well as to develop reliable and effective predictive models based on Artificial Intelligence (AI). As a preliminary step toward implementation, this study describes the evaluation of the application using various usability tools, with the aim of optimizing its design and ensuring its adoption by users.

The structure of this communication is organized as follows: After this introduction, Section II outlines the methodology used in the development and evaluation of the CICERONE telemonitoring application, detailing the iterative design process and the user-centered approach. Section III presents the results obtained from the usability evaluations conducted on the different prototypes, focusing on the user experience and the adjustments made during each design phase. In Section IV, we analyze the findings from the usability tests and discuss the implications of the results, particularly in terms of system performance, user feedback, and the challenges encountered during the integration of external devices.

II. Methodology

A. Objective

CICERONE is a multimodal telemonitoring platform developed to collect home data from high-risk COPD patients. This tool aims to promote the identification of new relevant predictors and the creation of an explainable clinical support system, based on artificial intelligence, designed to predict exacerbations of the disease in a personalized manner. The designed solutions are being evaluated with a cohort of COPD patients treated by the Pulmonology Department at the Hospital Universitario Puerta del Mar (Cádiz, Spain).

The overall architecture of the system is illustrated in Figure 1. The platform collects multimodal data, including physiological signals (e.g., oxygen saturation, heart rate), environmental parameters (e.g., air quality, temperature), and patient-reported outcomes through questionnaires. Given the sensitive nature of this health-related data, robust privacy-preserving mechanisms are essential. All data transmissions are secured using encryption protocols, and access is restricted based on user roles. All data collected during the main study are anonymized in compliance with the General Data Protection Regulation of the European Union (GDPR). Moreover, ethical considerations around data ownership, long-term storage, and secondary use of data for research have been systematically addressed in collaboration with clinical partners and ethics committees. For the daily reporting of information by the patient, a mobile application was developed to facilitate the direct acquisition of the aforementioned data and allow integration with the sensor ecosystem that accompanies the patient, thus optimizing data collection. The development of the application has taken into account previous experiences [13] [14], and this work describes the methodological aspects and the results of the development.

B. User-centered development

Given that COPD requires an approach that combines efficiency and usability, the design of the system for use in the home environment was developed with the patients' needs in mind.

The development of the mobile application for users was carried out using an iterative and incremental development model, involving a multidisciplinary team and the patients themselves as end users. The process began with a conceptual design that was transformed into an initial prototype through a mock-up. This prototype underwent several cycles of performance testing, usability evaluations, and design adjustments. In response to suggestions and improvements, incremental enhancements were implemented, leading to an intermediate prototype. It was a mobile application programmed in Java for Android, which was tested again to evaluate its performance and usability.

To measure overall satisfaction with the system, the standard System Usability Scale (SUS) [15] was used, which allowed for the evaluation of two specific dimensions: usability and capacity. Additionally, structured interviews were conducted with each participant to obtain qualitative feedback. Among the quantitative metrics used to assess usability were the time required to complete tasks and the overall score obtained on the SUS scale. These results were compared for the initial, intermediate, and final prototypes.

C. System Usability Scale (SUS)

The SUS is a widely used tool to assess the usability of products and systems, including software, hardware, mobile applications, and websites [15]. It has become a reference standard due to its simplicity, versatility, and robustness in obtaining quantitative data about the user experience.

The SUS consists of a ten-item questionnaire, where participants rate each statement on a five-point Likert scale, ranging from "Strongly disagree" (1) to "Strongly agree" (5). The questions alternate between positive and negative items to reduce response biases, and they are as follows:

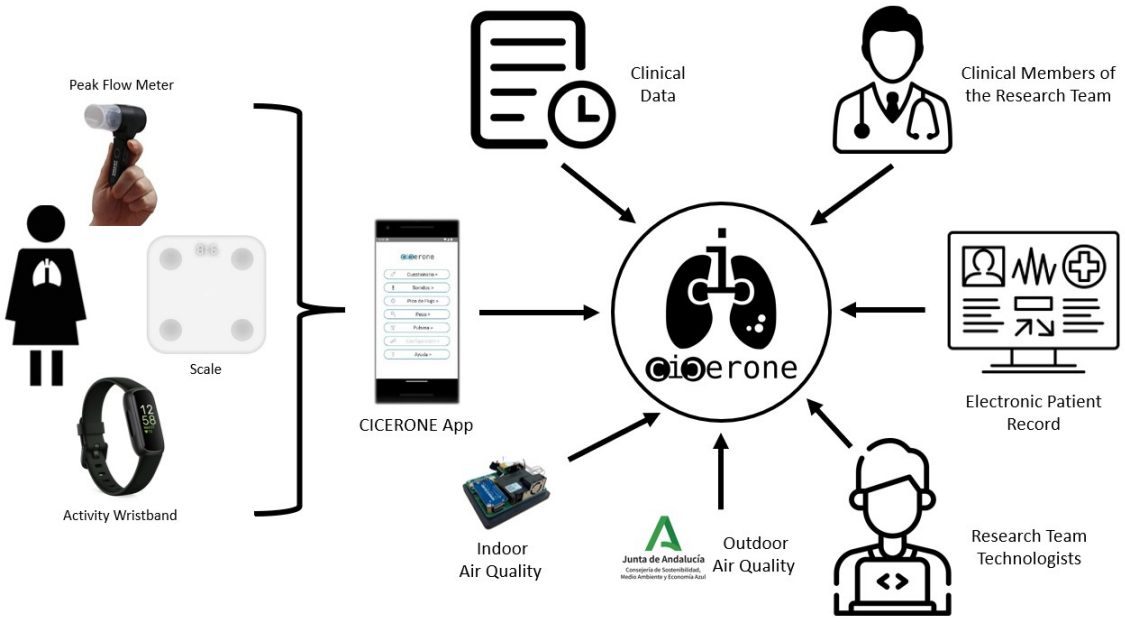

Figure 1. CICERONE Project Architecture.

1) *I think I'd like to use this app often.*
2) *I found the app unnecessarily complex.*
3) *I thought the app was easy to use.*
4) *I think I would need a technician's support to use the application.*
5) *I found the various features of the app to be well-integrated.*
6) *I thought there was too much inconsistency in this app.*
7) *I imagine that most people would learn how to use this app very quickly.*
8) *I found the app very complicated to use.*
9) *I felt very confident using the app.*
10) *I needed to learn many things before starting with this app.*

This questionnaire generates an overall score ranging from 0 to 100, as illustrated in Figure 2, where a higher score indicates a better perception of the usability of the evaluated system.

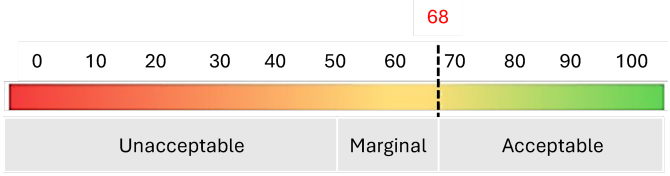

Figure 2. System Usability Scale.

To obtain the usability scale score, the following procedure is used. For odd-numbered items (positive), 5 is subtracted from the total sum; while for even-numbered items (negative), the total sum is subtracted from 25. The sum of both obtained values is then multiplied by 2.5 to scale the score, thus obtaining the final usability scale value (Equation 1).

$$X = \sum Points of Odd\ Statements - 5$$

$$Y = 25 - \sum Points of Even\ Statements$$

$$SUS\ Score = (X + Y) \times 2.5$$

A score of 68 or higher is considered to indicate that the usability obtained in the evaluation is acceptable.

D. Development Process: User-Centered Design

The design of a system for the home care of COPD patients must prioritize both efficiency and usability. To achieve this, it is essential to involve users throughout the entire development process, following a User-Centered Design (UCD) approach. This iterative and incremental method ensures that the needs and characteristics of the patients are properly considered, with the active participation of a multidisciplinary team and the end users.

The design process of the CICERONE application had four stages: requirements analysis, design, implementation, and launch. The design and implementation phases were carried out iteratively, allowing for continuous improvements based on new versions and user feedback.

In the initial analysis, a multidisciplinary team, composed of experts in pulmonology, usability, nursing, and engineering, conducted a field study to gather information and define the initial requirements. During the design phase, a first prototype (P1) was created using software tools to develop a mock-up. This mock-up underwent usability testing, leading to the implementation phase, where a high-fidelity prototype (P2) was developed in Android Studio and evaluated by a new study group. These tests were supervised by usability experts and a nurse, allowing the identification of problems and suggestions

for improvement that facilitated the development of a new prototype (P3), which was finally evaluated by a group of COPD patients.

1) Evaluation of Prototype P1: Prototype P1 was created using the Figma tool. This prototype simulated the application online, and installation was not required by the participant, who had the freedom to navigate through the different modules and complete activities to test its functionality and usability. In this prototype, the modules for communication with the peak flow meter and the activity bracelet were not available. The usability evaluation of this prototype was conducted with 11 participants, with an average age of over 50 years, using an electronic version of the SUS questionnaire, implemented using Google Forms.

2) Evaluation of Prototype P2: Prototype P2 was created using Android Studio. The resulting app was installed on the participant's mobile device, which they used in a supervised manner during the evaluation. This prototype did not include the module for communication with the peak flow meter, and the usability evaluation was conducted with 7 participants, again with an average age of over 50 years. The interview to complete the SUS questionnaire was conducted in person.

3) Evaluation of Prototype P3: This evaluation was conducted with 13 COPD patients, with an average age of over 60 years. The methodology employed was as follows. First, the patient was informed about the project and its objectives, and informed consent was obtained. General data on their medical history and lifestyle (physical exercise and habits) were collected. Subsequently, the level of dyspnea was assessed using the modified Medical Research Council (mMRC) dyspnea scale. After that, a cognitive test was completed using the Mini-Mental State Examination (MMSE) to assess the patient's cognitive abilities. Next, the application was installed on the patient's device along with an explanation of its functioning and that of the necessary external devices (peak flow meter, activity bracelet, and air quality meter). Various informational sheets with basic visual instructions for handling each device were provided. After installation, the patient performed an initial guided test, after which they answered usability questions (SUS scale described earlier), as well as a final interview with three open-ended questions regarding usage, two about learning, and one about user satisfaction:

1) *Do you consider a system like the one proposed by the project necessary?*
2) *What difficulties did you encounter while using the application?*
3) *Were there any technical issues during the session?*
4) *Were you able to complete all tasks without assistance?*
5) *Did you find it difficult?*
6) *Do you like the idea of using devices and mobile applications for self-monitoring your lung disease?*

To gather information about the patient's expectations, two questions were asked:

1) *Would you like to use this system in the future?*
2) *Do you think this system could be useful for other types of patients?*

The conduct of these final interviews with open-ended questions allowed participants to express comments, suggestions, or any aspect they considered relevant about the system. Moreover, it provided the opportunity to gather a comprehensive view of the user experience, combining objective measurements with subjective assessments.

E. Participants and Ethical Considerations

The study involved the collaboration of 31 participants. The evaluation of prototype P1 was conducted with 11 subjects, prototype P2 was evaluated by 7 participants, and the final version of the tool was tested by 13 patients, recruited by the Pulmonology and Allergy Unit of the Puerta del Mar University Hospital in Cádiz. The study was approved by the Coordinating Committee of Biomedical Research Ethics of Cádiz (CICERONE code, 29.23).

III. RESULTS

A. Design Phase

The first prototype was designed based on the initial requirements. The application included graphic icons, visual indicators, and text screens to represent information and actions, allowing users to interact directly with the graphic elements. It was designed for individuals over 60 years old with potential sensory deficits, compensated by a simplified design, enhanced visual stimuli, and minimal attention and memory load. Six main modules were incorporated: (1) respiratory symptom questionnaire (Likert-type questions) and two games to assess psychomotor abilities, (2) recording of cough and speech sounds, (3) evaluation of respiratory function through peak flow measurement, (4) weight, (5) reading of physical activity and sleep quality data measured by a smart bracelet, and (6) help module with video tutorials on handling all system elements. The mock-up developed in Figma is shown in Figure 3.

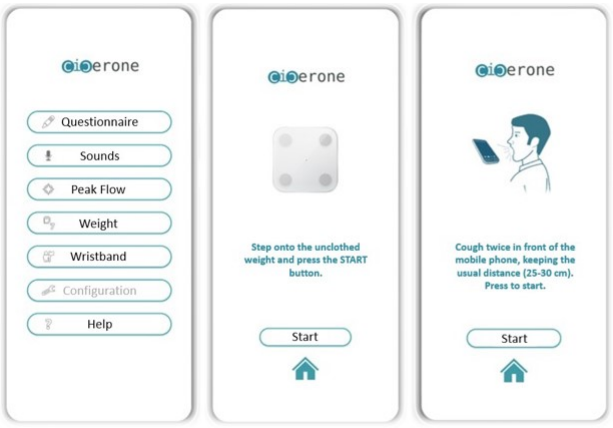

Figure 3. Some screens from the mock-up design created with Figma.

72.8% of the participants exceeded the average SUS usability score (68%), indicating the need for improvements in the prototype. Aesthetic and functional adjustments were made for a better user experience.

B. Implementation Phase

The first high-fidelity prototype (P2) underwent two redesign iterations to address usability deficiencies. The content design was adjusted, prioritizing a simple and understandable design for older individuals. The control interface was modified, aesthetic aspects were adjusted, and software stability issues were resolved. With these improvements, prototype P3 (shown in Figure 4) was developed and evaluated, resulting in a high level of perceived usability.

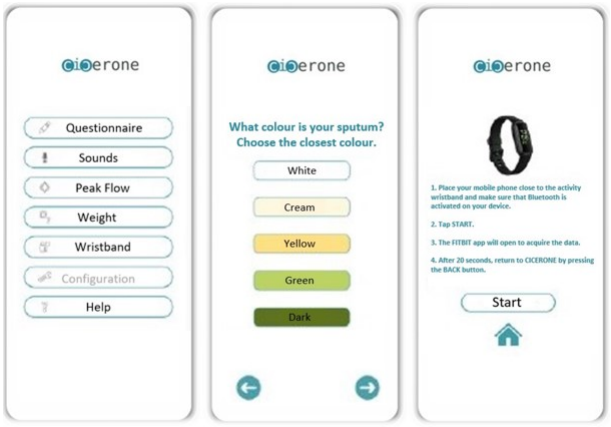

Figure 4. CICERONE Mobile Application.

The evaluations during the implementation phase were conducted in person. The average and standard deviation of the SUS metric for prototypes P1, P2, and P3 released in each iteration of the design were 80.68 (SD 12.75), 87.5 (SD 5.59), and 76.34 (SD 8.58), respectively.

Figure 5 shows the histogram with the SUS scores obtained from the evaluation of each prototype. In the case of prototype P1, all participants considered the usability level acceptable, with participant 6 reporting the lowest usability level (77.5). Unlike prototype P1, which had a mean perceived usability level of 80.7, the mean usability level of prototype P2 increased to 87.5. This prototype addressed most of the usability issues identified in P1.

The evaluation of P3 was conducted with a group of 13 COPD patients. The subjects evaluated the complete solution, including the app, peak flow sensor, and activity bracelet.

The average usability value obtained in the evaluation session of prototype P3 was 76.3. 23.1% of the patients considered the usability level to be marginal, without dropping below a minimum value of 60, despite incorporating the use of external devices to the application in this phase, which added complexity. Patients 1, 2, and 11 reported issues with linking and communication between the devices and the app. Despite the expected decrease from adding the layer of communication with real devices, the average usability level remained at good levels, close to excellent.

Finally, Figure 6 shows the average response given for each question in the usability questionnaire, according to the three design stages described.

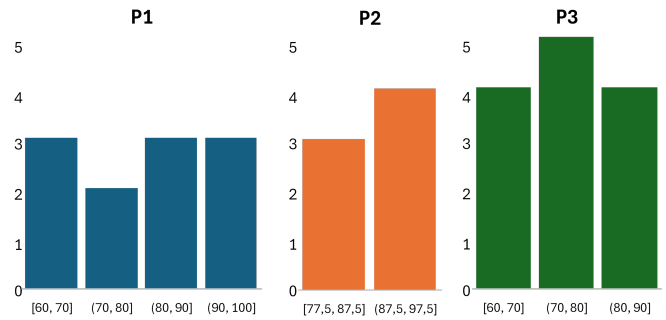

Figure 5. Histograms of the SUS metrics obtained from all participants in the evaluation of the P1, P2, and P3 prototypes of the CICERONE App, released in each iteration of the design.

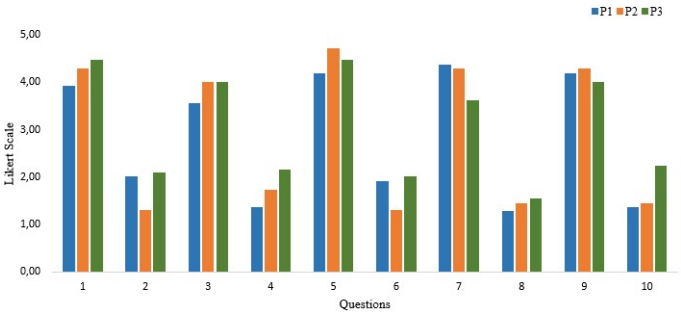

Figure 6. Comparison of results across different usability questions.

IV. Discussion and Conclusions

This study presents the development and evaluation of an application for the telemonitoring of patients with COPD, based on the recording of symptoms, sounds, and physiological parameters during both day and night. Usability tools and a user-centered design approach were employed to optimize its adoption.

The usability evaluation, conducted in three phases, showed that user responses improved as the prototype developed, indicating that iterative enhancements positively affected user perception. The platform is designed to minimize patient burden while enabling meaningful data collection, requiring less than five minutes per day for reporting via sensors or questionnaires. This low time demand supports adherence and reduces disruption, which is especially important for chronic conditions like COPD. Future evaluations will focus on user satisfaction, long-term engagement, and improvements in self-management to ensure the platform becomes a seamless, supportive part of daily life.

In terms of perceived complexity, the initial prototypes (P1 and P3) obtained similar scores, albeit for different reasons: P1, due to its simplicity as a simulation without full functionality; P3, due to its integration into the patient's device with technical assistance during the setup. Ease of use was better rated when no device linking was required, highlighting the importance of technical support during the implementation phase, especially for older users.

Moreover, younger participants and those with greater technological familiarity better identified the integration of functionalities and design consistency, while older users reported more difficulties and less confidence in using the application. These factors also influenced perceptions of the learning speed and the need for training.

The open feedback from participants highlighted the potential utility of the application in healthcare. However, some users expressed a preference for a simpler solution without reliance on mobile phones, while others showed willingness to continue using it after the study, reflecting a generally positive acceptance.

Prototype P2 received the best scores, standing out as the most intuitive and reliable, reflecting improvements over the previous P1 stage. The latter was perceived as limited in functionality and ease of use, underscoring the importance of early feedback in development.

On the other hand, P3 showed a high SUS metric, though lower than P2, with advancements in integration and usability but persistent challenges in terms of user confidence and design consistency, particularly among older users. A key finding was the progressive reduction in the need for technical support, indicating that successive iterations favored intuitiveness and functional integration.

In conclusion, the usability analysis based on the SUS scale allowed for the identification of significant differences between the development stages, emphasizing the importance of an iterative approach to optimize the user experience. The results highlight the relevance of a user-centered iterative development process to improve the usability and acceptance of telemonitoring applications. As future work, a key aspect to consider is the platform's scalability for deployment in diverse clinical contexts. This involves not only ensuring the technical capacity to handle an increasing number of patients and devices but also adapting the solution to the various regulations, technological infrastructures, and clinical workflows found across different healthcare systems. Integration with heterogeneous electronic health records, interoperability with standards such as HL7 (Health Level Seven) or FHIR (Fast Healthcare Interoperability Resources), and compliance with data protection regulations such as GDPR (General Data Protection Regulation) or HIPAA (Health Insurance Portability and Accountability Act) present significant challenges. These aspects will be addressed in future phases of the project to enable effective and sustainable large-scale adoption.

ACKNOWLEDGMENT

This study is part of the R&D project CICERONE. Grant PID2021-126810OB-I00 funded by MICIU/AEI/10.13039/501100011033 and by ERDF/EU.

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